ALMY

An Investigation of Friction Clutches

Mechanical Engineering

B. S.

1911

AN INVESTIGATION OF FRICTION CLUTCHES

BY

WILLIAM HERBERT ALMY

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1911

UNIVERSITY OF ILLINOIS

May 29 1911

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

William Herbert Almy

ENTITLED An Investigation of Friction Clutches

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

O. A. Leutwiler
Instructor in Charge.

APPROVED: G. A. Goodenough

Acting HEAD OF DEPARTMENT OF Mechanical Engineering

CONTENTS

CHAPTER V

AN INVESTIGATION OF FRICTION CLUTCHES

INTRODUCTION

In choosing this subject for investigation the writer was influenced by an interest in the subject of friction and its applications, and by the fact that a manufacturer was willing to furnish a number of clutches for test purposes.

Since this is the first work of the kind attempted at the University difficulties arose in collecting the required mechanism and in finding suitable power for its operation.

The present investigation can be but a meager introduction to the work that may be done at a future time when proper facilities are at hand.

In making these tests the following lines of investigation were attempted:

To determine the capacity of a line of clutches in pounds at one foot radius

(a) When the load is applied after the clutch is set by throwing in the lever.

(b) When picking up the load by throwing in the lever.

To determine the force necessary at the lever handle to transmit any load up to the rated capacity.

To determine the actual axial pressure on the discs cor-

responding to the known effort applied at the lever handle.

To determine the actual coefficient of friction of the several materials of which the discs are made when used in contact with cast iron.

To determine the apparent coefficient of friction on the basis of torque at one foot radius and the axial force exerted on the tapered sleeve by the clutch lever.

To compare the different materials for friction surfaces used in these tests.

It is expected that some points will come up which will prove of value in a subsequent design of a universal clutch testing machine.

Of the clutches usually found in factories the following types or modifications of them are most common:

(a) Plane disc.

(b) Cone.

(c) Rim and shoe.

CHAPTER I

DESCRIPTION OF CLUTCH

The clutch used in these tests was furnished by the Havana Manufacturing Company, Havana, Illinois. It is a stock clutch except that the same pulley was used for the several sizes of friction discs, which were twelve, fourteen, sixteen and eighteen inches in diameter. This adaptation did not affect in any particular the normal action of the clutches and made it possible to test four sizes in one, simply by changing the discs.

Referring to the section view, Fig. 1, and to the photographs, Figs. 2 to 5, a cast iron plate A having a long hub B is keyed rigidly to the shaft. A pulley C having circular plates cast integral with it on each end of the hub rotates freely on the hub B. A circular cast iron plate D having a rim E on its ribbed side is keyed to the hub B at F after the pulley C is in place. This plate is free to move with the pulley axially but must revolve with B. The end of the hub B is threaded to take the collar G which carries the two levers H and H. When this collar is screwed into place the step K on the end of the lever nearest the pin,which holds it in place,is in contact against the rim E. It is obvious that any motion of the ends of the levers H and H away from the shaft centre will cause the disc D to press against the pulley C which in turn presses against the plate A. Between the plates are interposed free discs of suitable friction

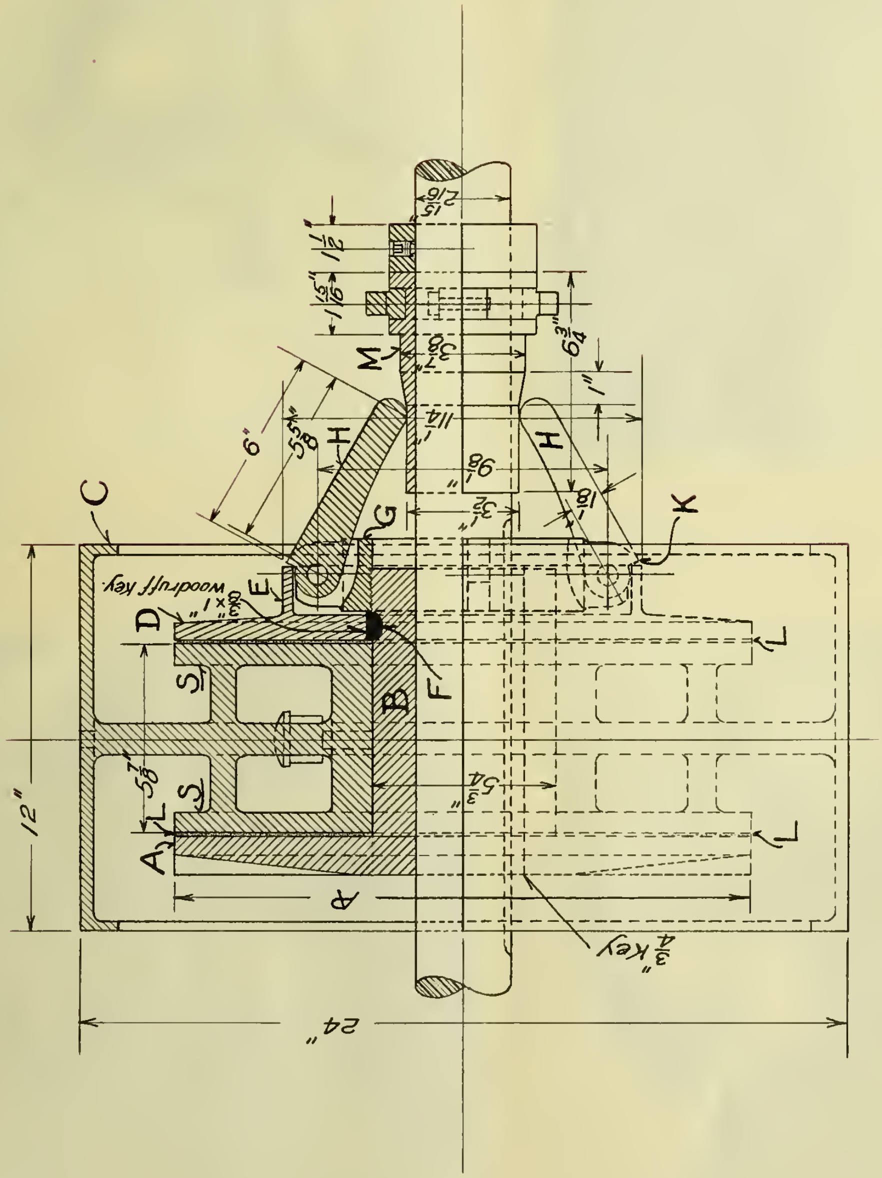


FIG. 1.

R | 12" 14" 16" 18"

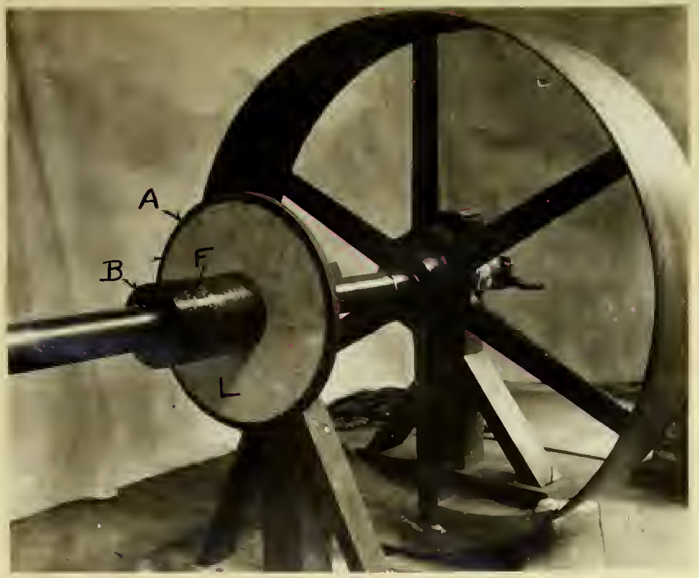


FIG 2

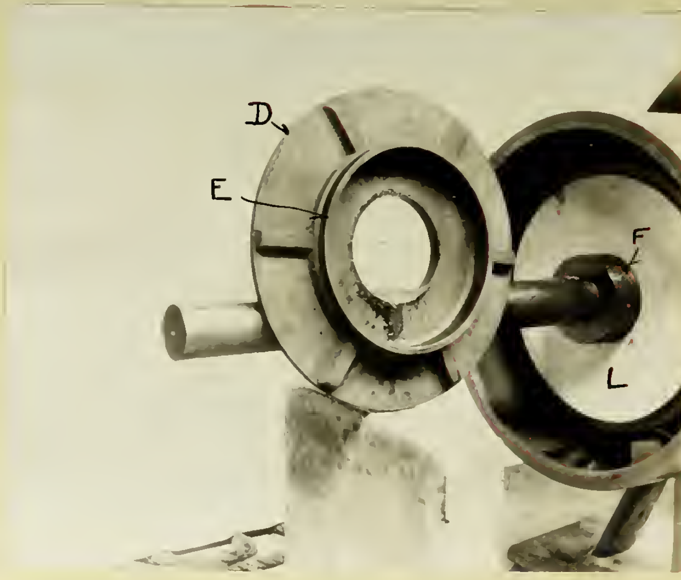


FIG 4

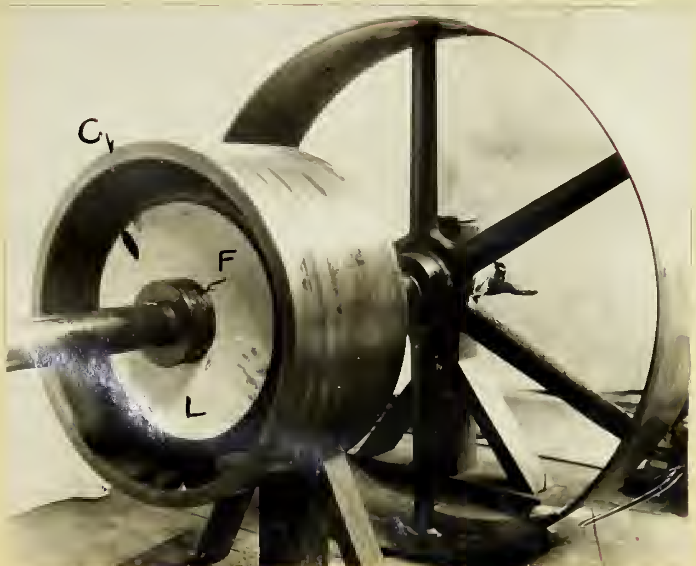


FIG 3

FIG 5

material. The outward motion of the small levers H and H is accomplished by the lever handle which moves the tapered sleeve [illegible].

CHAPTER II

DESCRIPTION OF APPARATUS

In Fig. 6 page 8 is shown diagramatically the form of apparatus used in testing this clutch. The shaft hangers were bolted to a rectangular frame of five inch by eight inch timbers across which two four inch by eight inch timbers were laid and bolted by 7/8 in. tee bolts to the channels provided in the floor. To tighten the belt all that was necessary to be done was to loosen the bolts and drive the frame over a little and tighten up the bolts again. The tightener pulley shown in the photograph on page 44 was used on account of the high concrete foundation under the belt wheel of the Ideal engine from which the power was derived. The function of the tightener placed as it was on the tight side of the belt was to keep the belt from touching this foundation. On the left hand side of the clutch pulley, Fig.6, the water inlet and the water scoop are shown.

The clutch lever was fulcrumed by a forged bracket to the adjacent hanger in such a position that the lever was at right angles to the shaft when the levers H and H were just about to pass the highest point of the angle on the sleeve. This insured right angle forces.

The Ideal engine mentioned above is rated at sixty horse-power at three hundred and twenty-five revolutions per minute. The steam pressure being higher than that at which the engine is rated, it was possible to get more than sixty horse-power.

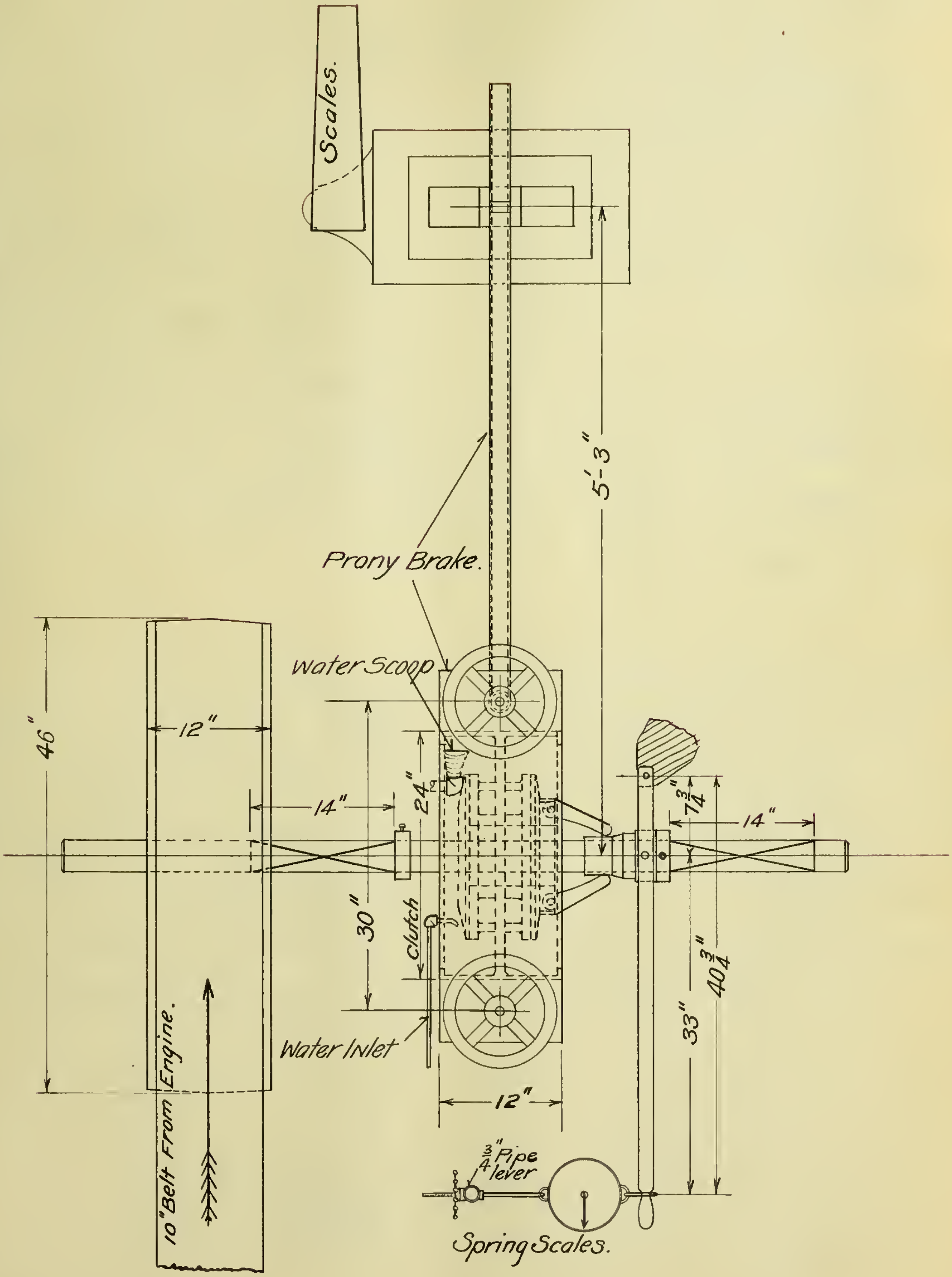

Scales.
Prony Brake.
5'-3"
Water Scoop
46"
12"
14"
24"
7 3/4"
14"
30"
Clutch
33"
40 3/4"
Water Inlet
12"
10" Belt From Engine.
3/4" Pipe lever
Spring Scales.

FIG. 6

The prony brake was built of wood in laminations, the two halves being held together by long bolts on which the nuts were in the form of hand wheels. The lever arm of the brake was made of 1-3/8 in. pipe and had a convenient length of five feet three inches from the center of the shaft to the knife edge.

The scales were of the platform type, having a capacity of 500 pounds. The instruments used consisted of a spring scale of 150 pounds capacity for use in reading the force required to throw in the clutch lever,and a tachometer for taking readings of revolutions per minute at any instant.

The pulley was flanged so as to allow the cooling water to be held in the r im. The heat was so great that some means had to be provided for scooping the water out as fast as it came in thus preventing the clouds of steam which at first enveloped the apparatus.

The shaft was two and fifteen-sixteenths inches in diameter. The position of the old keyway and the shortness of the shaft made it necessary to have the clutch between the bearings. Every time new discs were put in it was necessary to slip off the belt and raise the clutch, shaft,and drive pulley from the bearings and move them to one side to be taken apart. Such difficulties would not occur in case of a carefully designed apparatus.

CHAPTER III

METHOD OF TESTING

Three men were necessary for making the tests:

(1) One handled the engine and operated the clutch lever.

(2) One observed the revolutions of the clutch shaft.

(3) One took the prony brake readings.

The operation was as follows: After the clutch lever was set by pulling the handle by means of the spring scales, the prony brake was gradually applied until it was finally set or locked, thus causing the clutch to slip. At the instant slipping occurred simultaneous readings of revolutions and scale beam were taken. After the clutch slipped the transmitted load dropped off and readings were again taken and the brake released. This was continued until the torque was too great for the engine to slip the clutch after which the brake was tightened and the lever thrown in to determine the pick up capacity.

In order to determine the actual pressure on the discs corresponding to the known effort applied at the lever handle, the clutch proper without the pulley was put in a Riehle testing machine as shown in Fig. 7, page 11. The collar P, Figs. 8 and 9, which is integral with the short shaft takes the upward thrust of the hub B, collar G, and disc A. These move upward due to the operating lever on the tapered sleeve M. The actual pressure that otherwise would be between the discs is thus easily measured

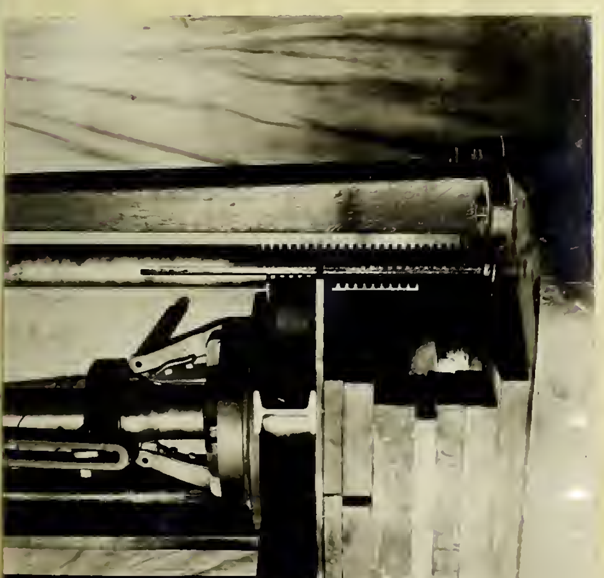


FIG. 7

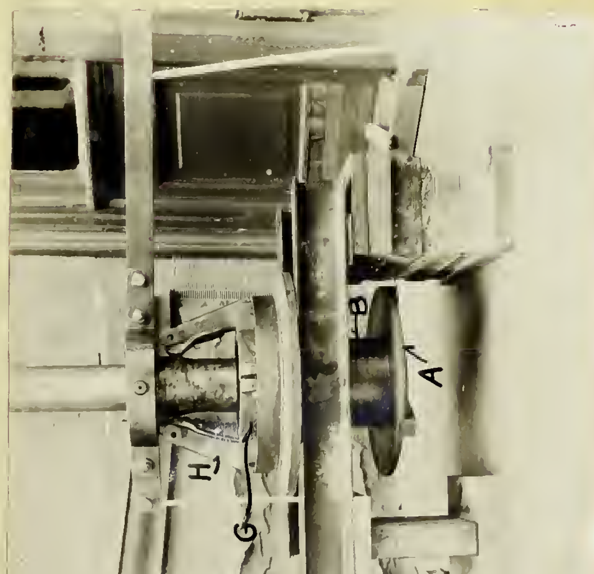


FIG. 8

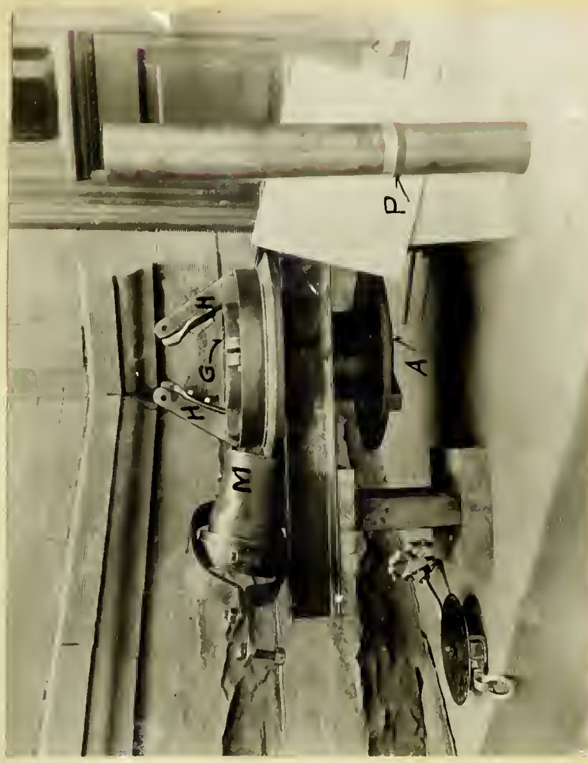


FIG. 9

FIG. 10

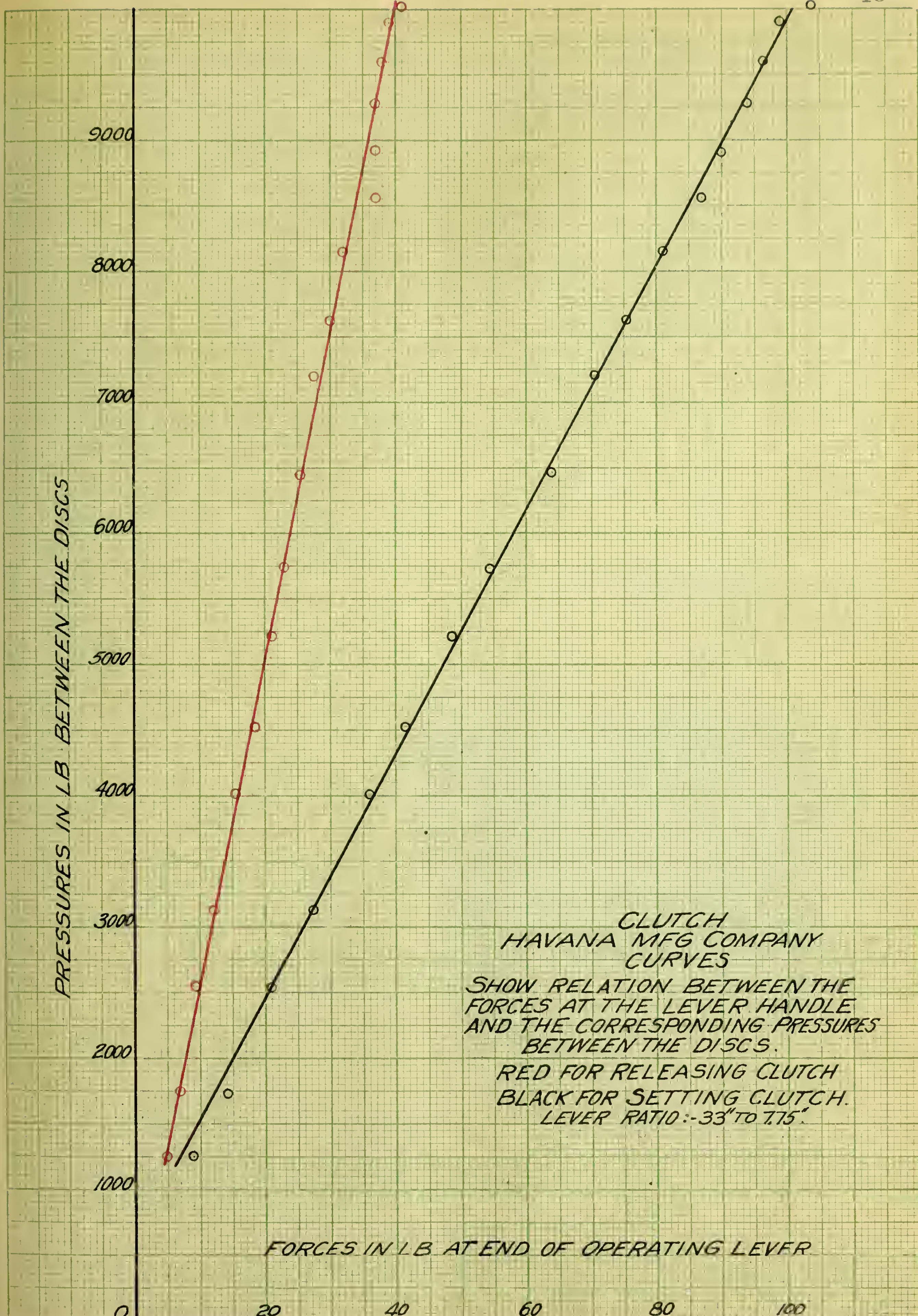
DATA-1

CALIBRATION OF HAVANA DISC CLUTCH
IN RIEHLE TESTING MACHINE

Nº	FORCE IN POUNDS TO APPLY LEVER	FORCE IN POUNDS ON SCALE BEAM	FORCE IN POUNDS TO RELEASE LEVER
1	104	10022	41
2	99	9930	39
3	96.5	9610	38
4	94	9280	37
5	90	8900	37
6	87	8560	37
7	81	8135	32
8	75.5	7675	30
9	70.3	7192	27.5
10	64	6470	25.6
11	54.5	5733	23
12	48.75	5220	21
13	41.3	4525	18.25
14	36	4020	15.75
15	27.5	3130	12
16	21	2530	9.25
17	14.1	1735	7
18	9	1252	5

THE ABOVE VALUES HAVE BEEN CORRECTED BY ADDING THE WEIGHT OF LEVER AND SUBTRACTING THE EFFECT OF THE NET WEIGHT OF THE CLUTCH.

LEVER RATIO: 33 TO 7.75


PRESSURES IN LB BETWEEN THE DISCS
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
20
40
60
80
100
FORCES IN LB AT END OF OPERATING LEVER
CLUTCH
HAVANA MFG COMPANY
CURVES
SHOW RELATION BETWEEN THE FORCES AT THE LEVER HANDLE AND THE CORRESPONDING PRESSURES BETWEEN THE DISCS.
RED FOR RELEASING CLUTCH
BLACK FOR SETTING CLUTCH.
LEVER RATIO:-33" TO 7.75".

on the scale beam of the testing machine. The curve shown on page 13 gives the disc pressures corresponding to the efforts required at the lever handle.

CHAPTER IV.

FORMULAE

HORSE POWER--The horse power transmitted by the prony brake used in these tests is given by the following formula:

$$H.P. = \frac{F \times N}{1000} \quad \text{.......} (1)$$

in which F= force measured on the scales.

N= revolutions per minute of the brake pulley.

TANGENTIAL PULL--The tangential pull T at a distance of one foot from the centre of the pulley is given by the following formula:

$$T = F \times 5.25 \quad \text{.......} (2)$$

The tangential pull at one foot radius may be referred to a an equivalent pull at the mean radius of the disc. The product of this new pull and the mean radius gives what is known as the moment of friction.

Letting D represent the mean diameter of the friction discs

M " " moment of friction.

n " " number of friction surfaces

P " " actual pressure on the discs.

μ " " coefficient of friction.

we have $$M = \frac{\mu P D n}{2} \quad \text{.......} (3).$$

For the case considered, n=2. Substituting this value in (3) and solving for P we get

$$P = \frac{T_m}{2\mu} \quad \text{.......} (4)$$

in which T_m represents the tangential pull at the mean radius of

the discs, and has the following value

$$T_m = \frac{24T}{D} \quad \text{.......................... (5)}$$

Combining (4) and (5), we may readily find a relation between P, T, μ, and D as follows

$$P = \frac{12T}{\mu D} \quad \text{.......................... (6)}$$

It is evident that if the axial pressure exerted upon the discs corresponding to a given effort at the end of the clutch lever, is known, the tangential capacity of any disc for any material may be calculated, provided the coefficients of friction of the different materials on cast iron are known. Under ideal conditions the coefficient determined experimentally would give accurate results in calculating capacities of disc clutches but rarely if ever are such conditions met with; therefore, the coefficient used must be slightly smaller than for the ideal case.

Time did not permit of making experiments in the physical laboratory on the determination of the actual coefficients of friction of the friction surfaces. Knowing the static coefficients, the size of discs, and the pressure between them, probable horsepower transmitted by a clutch may be calculated by solving for M in formula (3) and using it in the well known formula for horsepower, namely

$$H = \frac{NM}{63025} \quad \text{.......................... (7)}$$

where M= moment of T_m in inch pounds

N= revolutions per minute of discs

It does not matter at what radius the tangential pull is applied provided its product with that radius equals M. The transmitted horsepower of a clutch after M is determined depends directly upon the revolutions per minute.

In calculating the tangential load that the clutch will pick up, the kinetic coefficient must be used instead of the static coefficient. The friction of the pulley on its bearing will help in picking up the tangential load but so slightly as to be neglected in calculations.

SAMPLE CALCULATIONS

Given: data from page 25 line 2,

R.P.M. of clutch pulley = 346

Force measured on scale beams = 100 pounds.

Substituting in formula (1)

$$H.P. = \frac{100 \times 346}{1000}$$

$$= 34.6$$

From the above data find the tangential pull at one foot from the centre of the pulley. Substituting the value of F in formula (2)

$$T = 100 \times 5.25$$

$$= 525 \text{ pounds.}$$

The mean diameter of the 18" disc from which this data was obtained is 11.875". A force of 57 pounds was necessary to set the lever. On page 13 is a curve which gives the values of P corresponding to values of the force exerted at the lever handle. Referring to this curve the value of P is found to be 5950 pounds Substituting these values of P, T, and D in formula (6) and solving for μ,

$$\mu = \frac{12 \times 525}{5950 \times 11.875}$$

$$= .0891$$

CHAPTER V

DISCUSSION AND CONCLUSIONS

The results obtained throughout the tests are on the whole somewhat disappointing although several things of interest have developed.

Some things connected with the clutch mechanism may have influenced its perfect operation. It was found that the pulley did not run true on its bearing causing a lateral motion of the rim; this lateral motion and the possibility that the cast iron friction plates were not faced true may have caused the variation noticed in the force required to operate the clutch lever. When the brake was free, that is, the clutch lever thrown out, and the engine running, the friction of the pulley on its hub-bearing and the rubbing of the discs due to their closeness to each other would keep the clutch pulley rotating. When the lever was thrown in and out a number of times the force necessary at the lever handle was found to be the same; but as soon as the brake was tightened and the clutch made to slip a different force was found necessary at the lever handle for each application of the brake.

The closeness of the discs mentioned above was caused by the clamping of the levers on the small diameter of the operating sleeve. If the tapered part of the sleeve were made longer this trouble would be relieved. The levers which bear on the sleeve should be made perfectly smooth and the friction plates should also be smooth and show no defects in the faces. Before making

tests on a clutch, the discs should be "burned in" by running with the discs lightly rubbing and then gradually increasing the pressure until the proper working conditions are arrived at. Care in the above points will favorably affect the working of the clutch.

If the friction discs were made more like rings, that is, were made with larger inner diameters the wear would be more uniform over the rubbing surfaces. The mean radius could be increased in this manner and a more powerful clutch would result. It was found that the outer areas of discs were scored and worn more than the inner areas. One cause of scoring and failure of the discs at the outer areas was due to the high speed. It might be mentioned here that the scoring and tearing occurred only in the case of fibre discs; the leather discs stood up well in this respect but showed that the speed corresponding to the pressure was too great as evidenced by skin burning of the leather. The conditions under which the discs were tested are not exactly the same as are found in practice, for the capacity of a clutch for picking up a load would be the load that the clutch will pick up from rest, give motion to, and finally bring up to speed. It is clear that the velocity of slipping is a maximum only for an instant at starting and decreases to zero as the load is picked up. In the present tests it was necessary to measure the load transmitted when the discs slipped at maximum velocity. The time required for taking readings was sufficient to allow excessive heating of the friction media. It seems, therefore, that picking up a load gradually and bringing the relative velocity of the discs to zero would approach more closely to the conditions of

practice than do the conditions of these tests.

As has been stated, the force required at the lever handle, when all adjustments remained unchanged, varied. The relation between the force exerted at the lever handle and the tangential load handled in transmission would be expected to vary approximately as much as the coefficient of friction of the materials used. These actual coefficients vary as much as thirty percent for the same materials. The relation between the force required at the lever handle and the tangential load handled when picking up a load should be fairly uniform, because the kinetic coefficient of friction is fairly well defined as a fixed value.

It was possible to plot curves from the major part of the data obtained. From the data shown on pages 27,41,& 42 no curves could be constructed as the results varied too much. The curves from the other data sheets though not clearly defined seem to follow the path of an increasing ratio between the forces at the end of the lever and the tangential loads handled. In two cases pages 36 and 40 the curves seemed to be concave downwards.

If many more observations could have been made before the discs became burned it is probable that a straight line might have been substituted for the curves. However, the general tendency of the curves shown is concave upwards which indicates an increasing ratio between the tangential pull and the force on the lever. The curve shown on page 13 is a straight line and since the curves under discussion are plotted with the same abscissae it follows that the "increasing ratio" mentioned above is due to elements outside of the clutch mechanism. An increase of the coefficient of friction with the increase of pressure or an in-

crease of the coefficient of friction with the temperature are likely causes.

The curves for leather discs on pages 29,31,32,& 34 show how near the leather discs come to picking up the same load that they will transmit without slipping. A leather disc will pick up from 75 to 95% of the load it will transmit without slipping. On the other hand it was found that the fibre discs in general will pick up approximately 25% of the maximum load transmitted.

For picking up a load at high speed and high pressure, leather discs are undoubtedly superior to fibre. It is doubtful whether or not leather discs will stand the destroying effect of prolonged heat as well as fibres. Fibre discs when used at proper speeds and pressures will probably outwear leather discs. Fibre discs do not change size or shape in use but leather discs shrink considerably and usually more on one side than on the other. The result of shrinking more on one side is to pull the

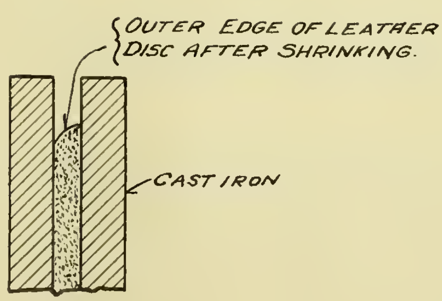


FIG. 11

outer edge on that side against the friction plates and wear it off. The accompanying figure shows the shape of the discs so affected. Shrinkage amounted to as much as one inch in diameter for an eighteen inch disc.

In the design of a universal clutch testing machine means should be provided for high torque,—about two thousand pounds at one foot radius. The clutch shaft should be driven by gears or through a gear set capable of several speed ratios. The power should be derived from a variable speed motor of large enough capacity to keep up the speed when the load is on. A higher speed than can be obtained through the gears should be arranged for by separate belted connection. The majority of tests require low speeds but high speeds will be necessary for determining the relation between speed, temperature, and coefficient of friction. The apparatus should be universal in respect to different sizes of the same type of clutch and if possible with respect to different types.

The same apparatus for determining transmitting capacities will answer for most types of clutches but for determining the internal pressures that exist at certain settings of levers, etc. a different machine will be necessary; it must permit of many changes and adjustments to meet the different shapes and types of clutches.

Some means should be provided for determining whether or not the friction surfaces creep a little before finally slipping.

The brake should be so constructed that it may be relieved quickly the instant that it grips the pulley. The trouble due to heating will be relieved by such an arrangement when measuring the load capacities in transmission. In conjunction with the above device means should be at hand for measuring the exact prony brake load at any moment without the necessity of having to balance a scale beam.

DATA Nº 2(a)

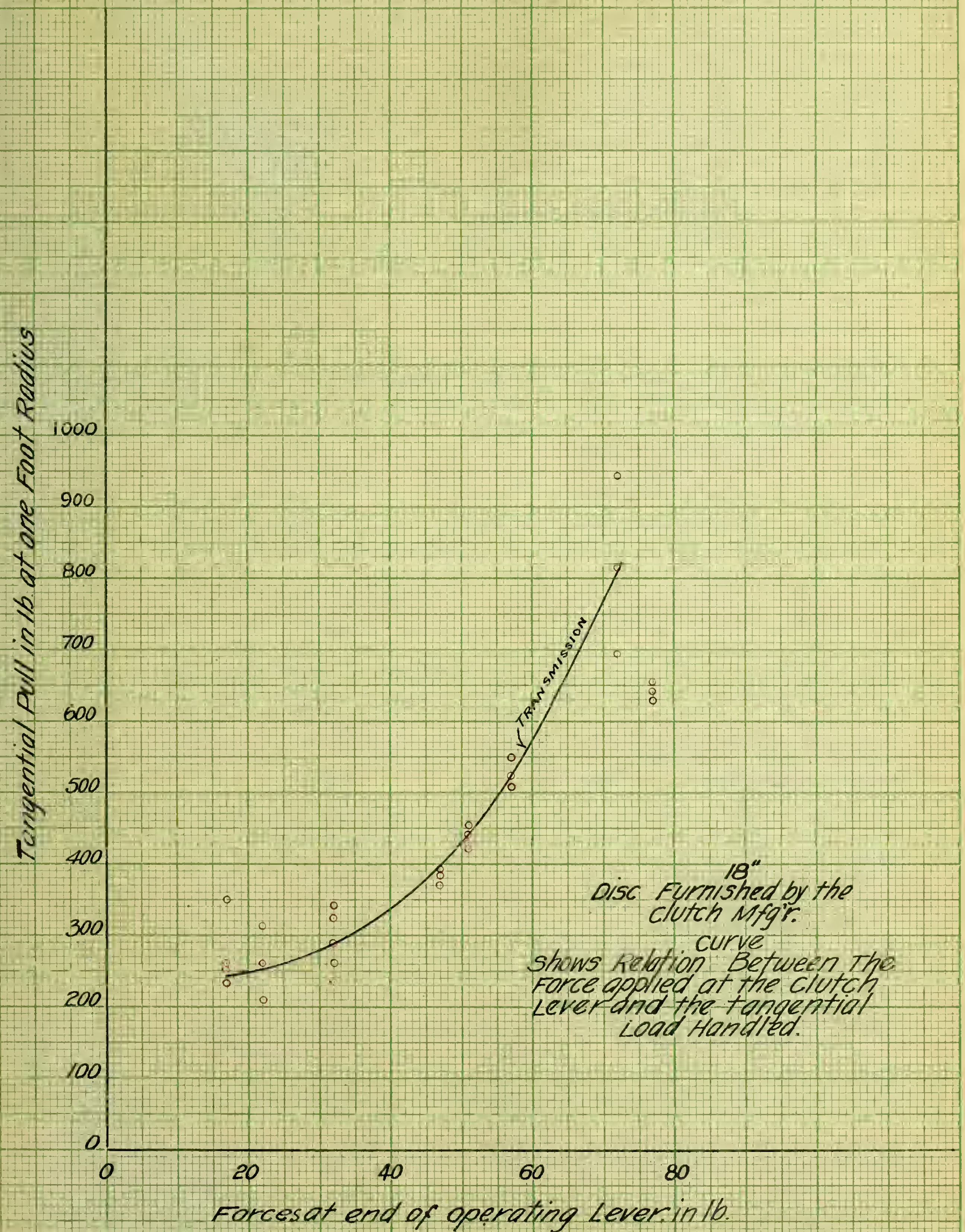
18" FIBRE SENT WITH THE STD. CLUTCH.

TRANSMIT LOAD						PICK UP LOAD.					
READING NUMBER.	FORCE IN LB. AT END OF LEVER	NET LB. ON SCALES	REV PER MIN OF CLUTCH	TANG'L LOAD IN LB. AT ONE FT. RAD.	REMARKS	READING NUMBER	FORCE IN LB. AT END OF LEVER	NET LB. ON SCALES	REV. PER MIN OF CLUTCH	TANG'L LOAD IN LB. AT ONE FT. RAD.	REMARKS
1	7	140	344			1	7	35	348		
2		185	340			2		50	348		
3		168	340			3		28	348		
4		160	338			4		30	346		
5		132	336			5		30	348		
6		145	342			6		32	346		
7	14	232	324			7	14	39	336		
8		205	336			8		30	340		
9		230	328			9		59	344		
10		220	336			10		37	348		
11		219	332			11		50	348		
12		202	340			12		32	348		
13	17	48	344	252							
14		50	348	262							
15		45	344	236							
16		67	346	352							
17	32	55	344	289							
18		45	342	236							
19		58	342	304							
20		50	342	262							
21		65	342	341							
22		55	344	288							
23		62	344	325							
24		55	346	288							
25		57	346	299							
26		54	344	283							
27	22	60	342	315							
28		50	342	262							
29		42	344	221							
30		42	348	221							
31		40	346	210							
32	47.5	75	344	393							
33		73	344	383							
34		73	344	383							
35		71	344	372							
36		73	346	383							
37	51.5	85	348	446							
38		87	344	456							
39		82	344	430							
40		81	346	425							

DATA Nº 2 (b)

18" Fibre Sent with The Std. Clutch.

Transmit Load						
Reading Number	Force in lb. at End of Lever	Net lb. on Scales	Rev Per Min of Clutch	Tang'l load in lb. at one Ft. Rad.	Remarks	
1	57	105	346	550		
2		100	346	525		
3		99	348	520		
4		97	346	509		
5		98	346	515		
6	77	125	346	655	oiled Discs	
7		120	344	630		
8		123	344	645		
9		125	344	655		
10		120	346	630		
11	72	190	346	998		
12		180	346	945		
13		155	342	815		
14		133	348	695		
15		180	346	945		
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						


Tangential Pull in lb. at one Foot Radius
1000
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
Forcesat end of operating Lever. in lb.
TRANSMISSION
18"
Disc Furnished by the
Clutch Mfg'r.
curve
Shows Relation Between The
Force applied at the Clutch
Lever and the tangential
Load Handled.

DATA № 3

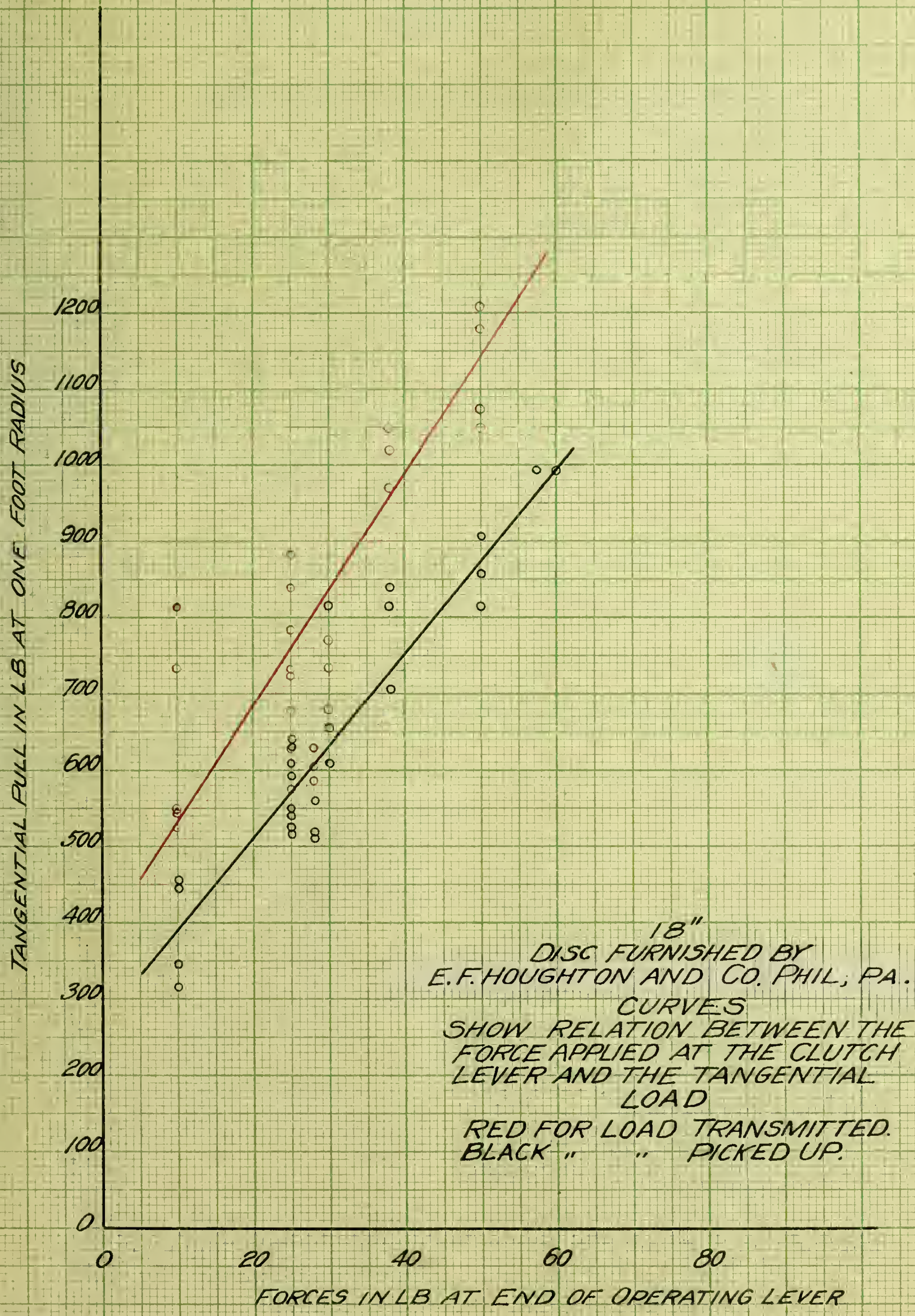
12" and 16" Discs From Diamond State Fibre Co.

TRANSMIT LOAD						PICK UP LOAD					
Reading Numbers	Force at end of Lever	Net lb. on Scales	Rev. Per min of clutch	Tang'l load in lb. at one Ft Radius	Remarks	Reading Numbers	Force at end of Lever	Net lb. on Scales	Rev Per min of Clutch	Tang'l load in lb. at one Ft Radius	Remarks
1	13	244	336	1280	16" Discs.						
2		147	340	670	"						
3		201	340	1060	"						
4		205	334	1065	"						
5		180	340	945	"						
6	20	105	343	550	12" Discs	6	20	55	345	189	
7		115	343	604	"			55	345	189	
8		105	342	550	"			70	344	367	
9		155	338	815	"			80	345	420	
10		255	231	1340	"						
11		230	235	1210	"	11		120	245	630	
12		245	239	1290	"	12		102	342	535	
13		235	277	1234	" no slip						
14	40	283	245		" " "						
15	30	159	348	835	16" Discs						
16		205	336	1065	"						
17		175	336	920	"						
18		290	268	1520	" no Slip.						
19		273	272	1435	" " "						
20		265	276	1390	" " "						
21						21	37	198	340	1040	
22						22	38	182	340	956	
23						23	42	205	340	1065	Smoke-odor
24											
25											

DATA-4

18" DISC FROM E. F. HOUGHTON AND CO.

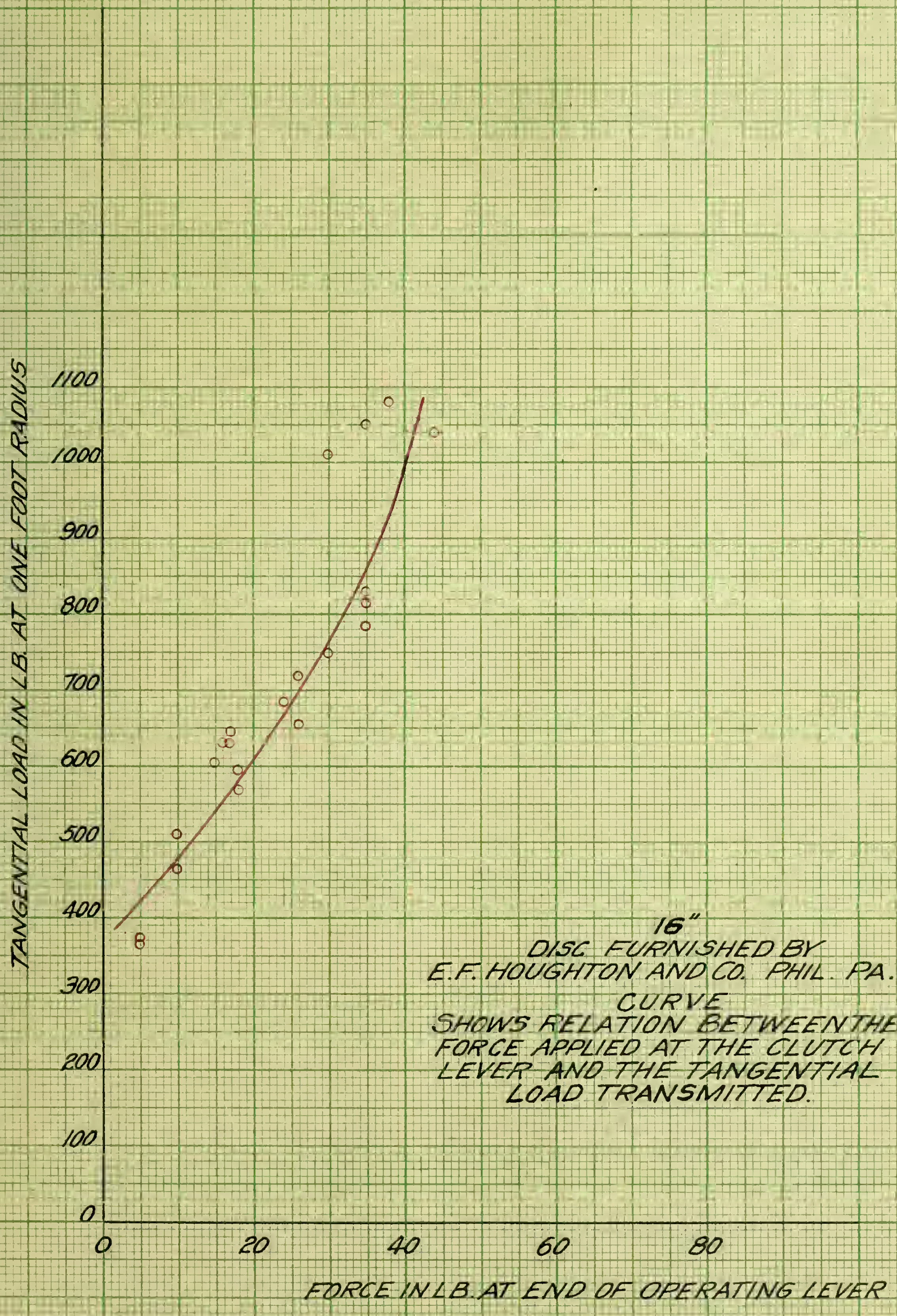
TRANSMIT						PICK UP					
Nº	LB. AT LEVER END	REV PER MIN	LB. NET ON SCALES	LB. TANG. PULL 1'-0" RAD.	REMARKS	Nº	LB. AT LEVER END	REV. PER MIN	LB. NET ON SCALES	LB TANG. PULL 1'-0" RAD	REMARKS
1	10	345	155	815		1	10	349	75	394	
2		344	140	735				345	87	457	
3		344	105	550				345	85	446	
4		343	100	525				342	87	457	
5		342	104	545				345	60	315	
6		343	105	550				347	65	342	
7		342	155	815				347	75	394	
8		343	105	550				345	65	342	
9		341	105	550				346	75	394	
10	25	337	130	682			25	348	120	630	
11		341	120	630				341	105	550	
12		337	120	630				340	103	540	
13		341	117	615				336	100	525	
14		337	150	786				335	115	610	
15		335	140	735				336	105	550	
16		333	138	725				336	105	550	
17		334	140	735				338	95	498	
18		335	120	630				339	85	446	
19		335	110	577				339	90	473	
20		337	110	577				340	90	473	
21		338	115	605				340	90	473	
22		340	100	525				342	85	446	
23		339	150	786				335	122	640	
24		341	160	840				337	115	610	
25		335	160	840				340	120	630	
26		331	168	882				335	118	629	
27		337	155	815				334	113	592	
28	28	331	120	630			28	337	107	560	
29		331	122	588				337	97	510	
30		335	123	645				337	99	520	
31		334	115	605				336	99	520	
32	30	334	140	735			30	336	125	657	
33		333	145	760				335	125	657	
34		334	130	680				335	115	610	
35	38	334	200	1050			38	328	160	840	
36		335	195	1020				332	155	815	
37		320	185	970				331	135	707	
38	50	327	230	1209			50	330	185	970	
39		328	225	1180				334	165	866	
40		322	200	1050				334	165	866	
41		324	205	1075				332	155	815	
42	57	331	190	997							
43	60	324	190	997							
44	60	330	190	997							
45	60	330									
46	60	332									

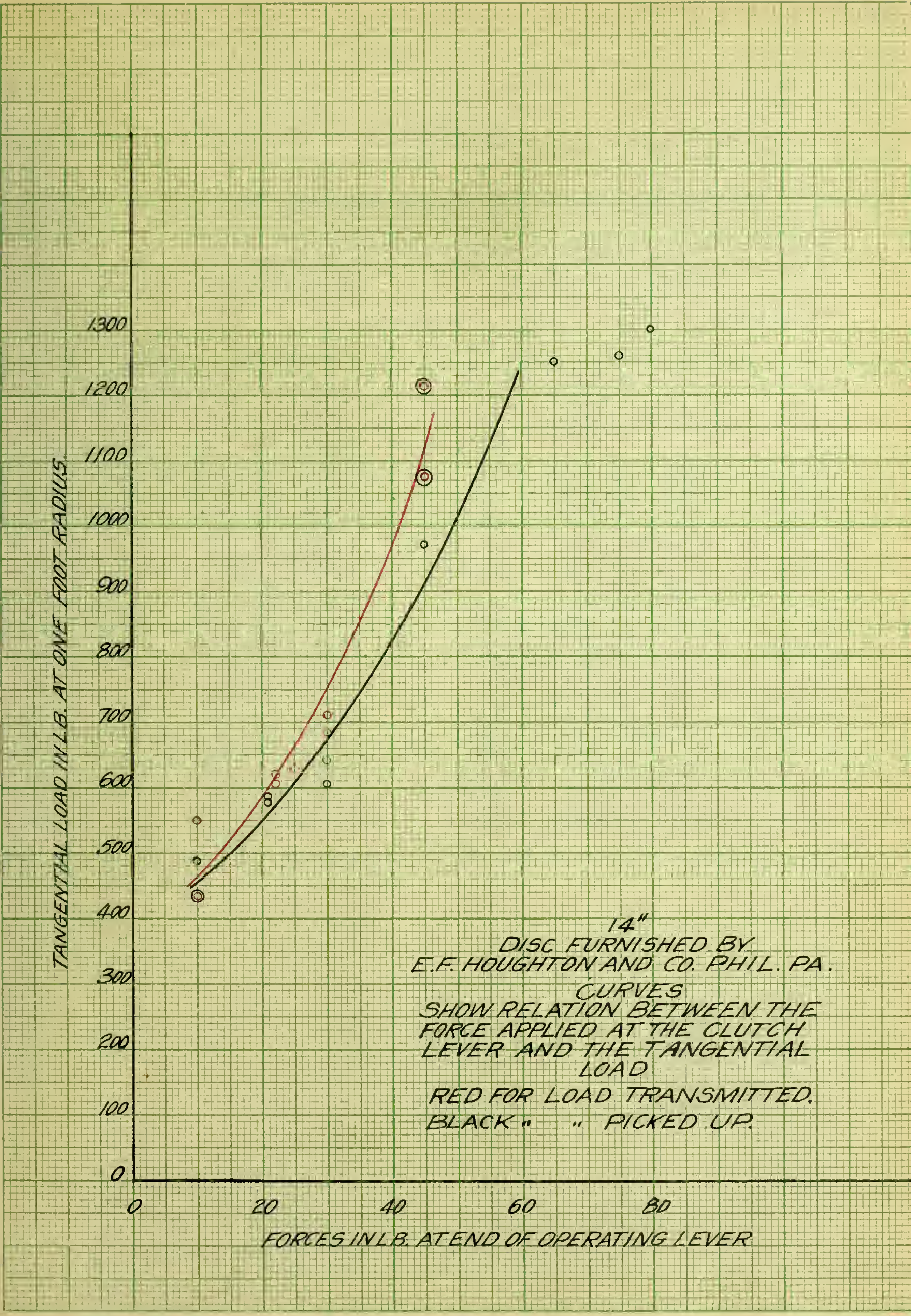

TANGENTIAL PULL IN LB AT ONE FOOT RADIUS
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
FORCES IN LB AT END OF OPERATING LEVER
18"
DISC FURNISHED BY
E.F. HOUGHTON AND CO. PHIL., PA.
CURVES
SHOW RELATION BETWEEN THE
FORCE APPLIED AT THE CLUTCH
LEVER AND THE TANGENTIAL
LOAD
RED FOR LOAD TRANSMITTED.
BLACK " " PICKED UP.

DATA-5

16" AND 14" LEATHER DISCS - E.F. HOUGHTON AND CO.

TRANSMIT						PICK UP					
Nº	LB. AT LEVER END	REV PER MIN	LB NET ON SCALES	LB. TANG. PULL 1'-0" RAD.	REMARKS.	Nº	LB. AT LEVER END	REV PER MIN	LB. NET ON SCALES	LB TANG PULL 1'-0" RAD	REMARKS
1	5	335	70	367	16" LEATHER						
2		335	70	367	" "						
3		335	71	373	" "	VALUES OF PICK UP PRACTICALLY					
4		335	71	373	" "	THE SAME AS FOR TRANSMIT					
5	10	338	97	510	" "						
6		339	89	467	" "						
7	15	329	115	605	" "						
8	16	326	120	630	" "						
9	17	327	120	630	" "						
10		327	123	645	" "						
11	18	336	108	568	" "						
12		338	113	595	" "						
13	24	333	131	687	" "						
14	26	330	125	655	" "						
15		330	134	720	" "						
16	30	325	192	1010	" "						
17		325	143	750	" "						
18	35	324	209	1100	" "						
19		328	155	815	" "						
20		335	149	783	" "						
21		328	158	830	" "						
22	38	324	215	1130	" "						
23	44	323	198	1040	" "						
24	10	335	105	550	14" LEATHER						
25		335	105	550							
26		337	83	436							
27	22	334	115	603							
28		334	118	620							
29	25	334	120	630		29	25	334	120	630	
30	30	333	135	708		30	30	333	122	640	
31		334	130	683		31		335	115	603	
32	45	330	205	1075		32	45	330	205	1075	
33		326	231	1212		33		326	231	1212	
34		327	205	1075		34		327	205	1075	
35		327	205	1075		35		327	205	1075	
36		327	205	1075		36		327	205	1075	
37		327	205	1075		37		327	205	1075	
38		330	203	1070		38		333	185	970	
39		327	205	1075		39					
40						40	55	337	119	625	
41						41	65	280	238	1250	
42						42	75	276	240	1260	
43						43	80	270	248	1300	

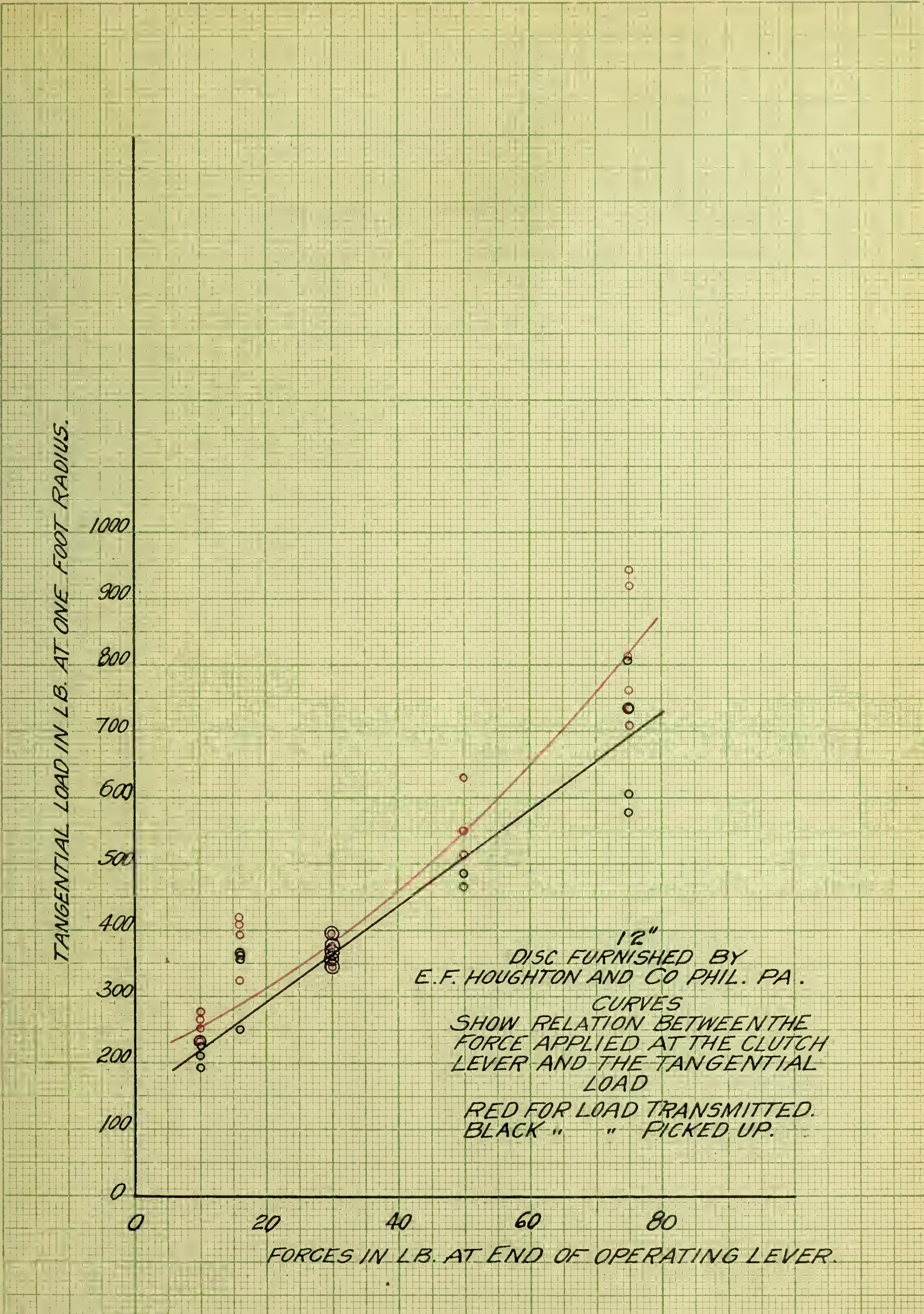

TANGENTIAL LOAD IN LB. AT ONE FOOT RADIUS
1100
1000
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
FORCE IN LB. AT END OF OPERATING LEVER
16"
DISC FURNISHED BY
E.F. HOUGHTON AND CO. PHIL. PA.
CURVE
SHOWS RELATION BETWEEN THE
FORCE APPLIED AT THE CLUTCH
LEVER AND THE TANGENTIAL
LOAD TRANSMITTED.


TANGENTIAL LOAD IN LB. AT ONE FOOT RADIUS.
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
FORCES IN LB. AT END OF OPERATING LEVER
14"
DISC FURNISHED BY
E.F. HOUGHTON AND CO. PHIL. PA.
CURVES
SHOW RELATION BETWEEN THE
FORCE APPLIED AT THE CLUTCH
LEVER AND THE TANGENTIAL
LOAD
RED FOR LOAD TRANSMITTED.
BLACK " " PICKED UP.

DATA-6

12" LEATHER DISCS - E. F. HOUGHTON AND CO

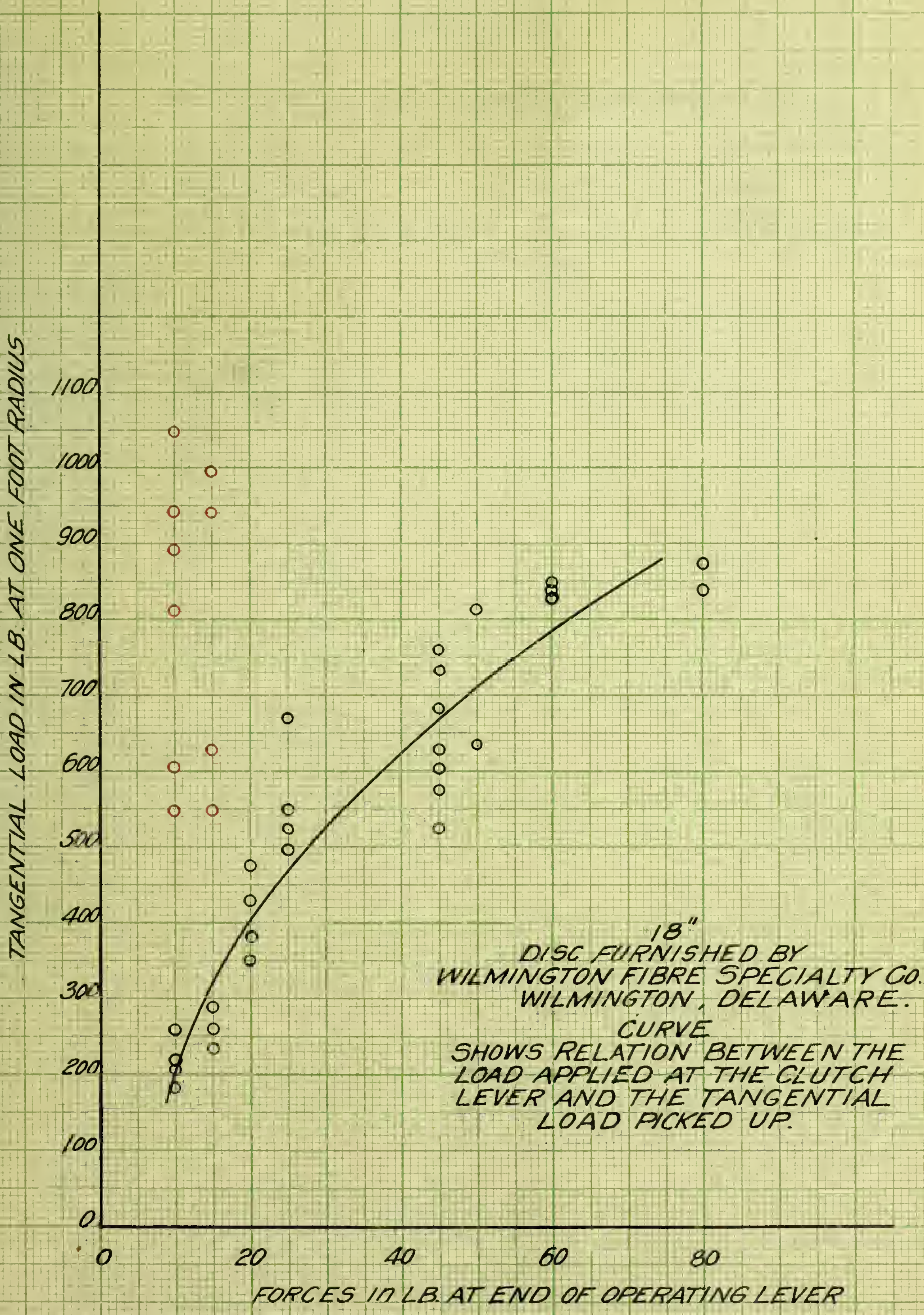
TRANSMIT						PICK UP					
Nº	LB. AT LEVER END	REV PER MIN.	LB. NET ON SCALES	LB. TAN'G PULL AT ONE FT RAD	REMARKS	Nº	LB AT LEVER END	REV PER MIN.	LB NET ON SCALES	LB. TAN'G PULL AT ONE FT. RAD.	REMARKS
1	10	335	53	278		1	10	335	45	236	
2		335	51	268		2		335	43	226	
3		335	53	278		3		335	45	236	
4		335	48	252		4		335	40	210	
5		335	44	232		5		335	37	194	
6	16	334	62	326		6		334	48	252	
7		335	80	420		7		336	70	367	
8		334	80	420		8		334	69	362	
9		334	78	410		9		334	68	357	
10		334	75	394		10		335	68	357	
11	30	334	75	394		11		334	75	394	
12		335	66	347		12		335	66	347	
13		335	72	378		13		335	72	378	
14		335	70	368		14		335	70	368	
15		335	68	357		15		335	68	357	
16		335	71	373		16		335	71	373	
17	50	334	120	630		17	50	335	93	488	
18		335	105	550		18		336	89	467	
19		335	98	515		19		336	98	515	
20	75	326	175	920		20	75	330	153	806	
21		328	180	945		21		334			
22		333	135	710		22		334	110	578	
23		334	145	762		23		335	115	604	
24		334	140	735		24		336	115	604	
25		334	155	815		25		334	140	735	


TANGENTIAL LOAD IN LB. AT ONE FOOT RADIUS.
0
100
200
300
400
500
600
700
800
900
1000
0
20
40
60
80
FORCES IN LB. AT END OF OPERATING LEVER.
12"
DISC FURNISHED BY
E.F. HOUGHTON AND CO PHIL. PA.
CURVES
SHOW RELATION BETWEEN THE
FORCE APPLIED AT THE CLUTCH
LEVER AND THE TANGENTIAL
LOAD
RED FOR LOAD TRANSMITTED.
BLACK " " PICKED UP.

DATA-7

18" FIBRE DISC - WILMINGTON FIBRE SPECIALTY CO.

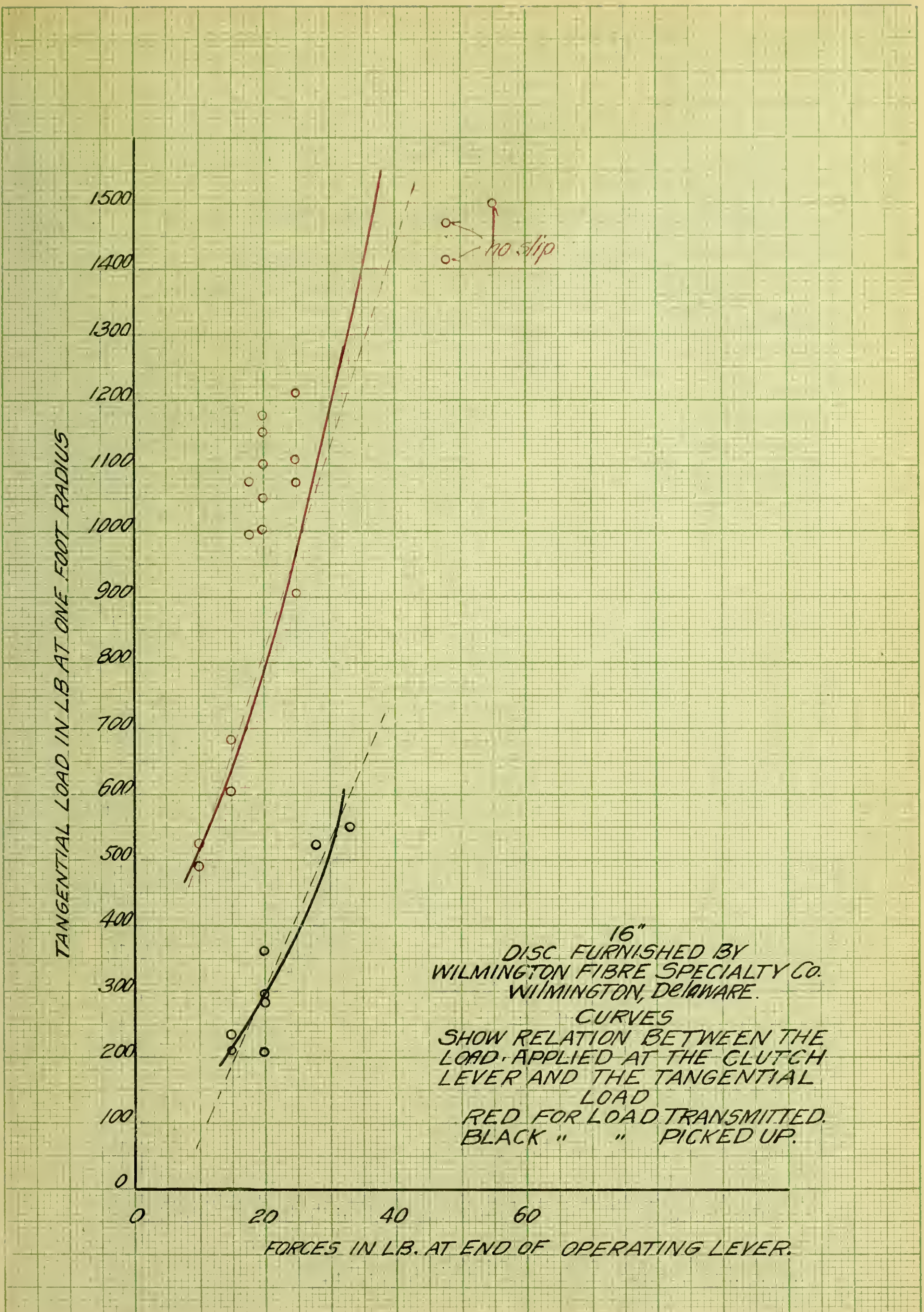
TRANSMIT						PICK UP					
Nº	LB. AT END OF LEVER	REV. PER MIN.	LB. NET ON SCALES	LB. TANG. PULL AT ONE FOOT RADIUS	REMARKS	Nº	LB. AT END OF LEVER	REV. PER MIN.	LB. NET ON SCALES	LB. TANG. PULL AT ONE FOOT RADIUS	REMARKS.
1	10	336	170	892		1	10	340	35	184	
2		338	170	892		2		340	40	210	
3		340	115	604		3		342	35	184	
4		336	200	1050		4		339	50	262	
5		340	105	550		5		341	40	210	
6		340	155	814		6		342	42	221	
7		339	180	945		7		341	40	210	
8	15	340	190	998		8	15	343	50	262	
9		339	105	550		9		341	50	262	
10		342	120	630		10		342	55	280	
11		340	120	630		11		343	45	237	
12		342	180	945		12		345	45	237	
13						13	20	340	90	473	
14						14		340	90	473	
15						15		342	82	430	
16						16		342	73	383	
17						17		342	67	352	
18						18		342	67	352	
19						19	25	336	130	672	
20						20		340	105	550	
21						21		340	100	525	
22						22		342	95	498	
23						23	45	334	115	604	
24						24		335	140	735	
25						25		335	120	630	
26						26		335	145	762	
27						27	50	334	118	639	
28						28		334	155	814	
29						29		334	118	639	
30						30		335	118	639	
31						31	60	328	160	840	
32						32		327	162	850	
33						33		328	162	850	
34						34		329	158	830	
35						35		329	161	845	
36						36	80	329	160	840	
37						37		326	167	876	
38						38		326	167	876	
39	45	326	195			39	45	334	115	604	1st Readings
40		322	225			40		338	110	577	on these discs
41	55	316	247		no slip						
		290	290		" "						
		280	300		" "						


TANGENTIAL LOAD IN LB. AT ONE FOOT RADIUS
1100
1000
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
FORCES in LB. AT END OF OPERATING LEVER
18"
DISC FURNISHED BY
WILMINGTON FIBRE SPECIALTY CO.
WILMINGTON, DELAWARE.
CURVE
SHOWS RELATION BETWEEN THE
LOAD APPLIED AT THE CLUTCH
LEVER AND THE TANGENTIAL
LOAD PICKED UP.

DATA-8

16" FIBRE DISC - WILMINGTON FIBRE SPECIALTY CO.

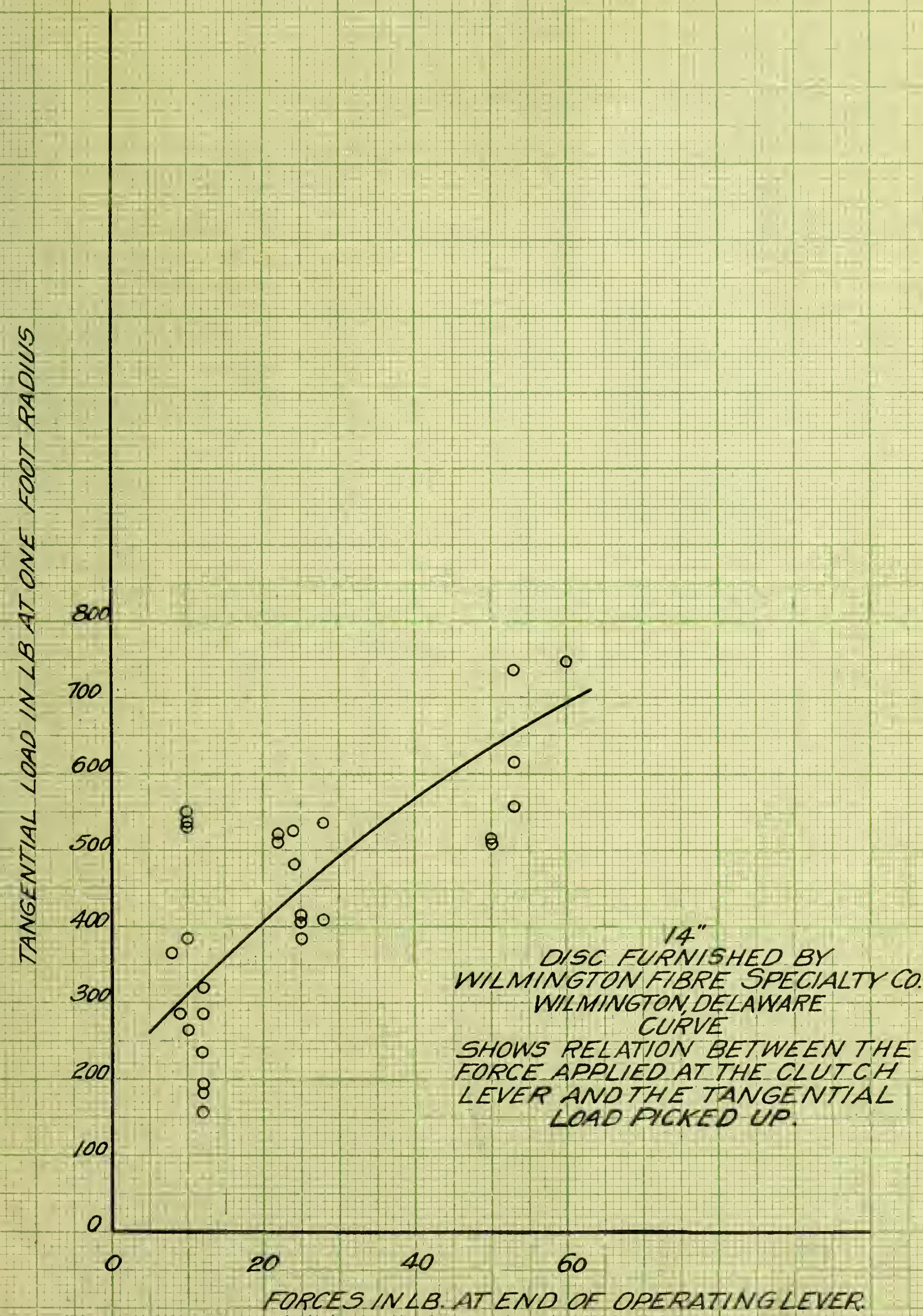
TRANSMIT						PICK UP					
No	LB. AT END OF LEVER	REV. PER MIN.	LB NET ON SCALES	LB. TANG PULL AT ONE FT. RAD.	REMARKS.	No	LB. AT END OF LEVER	LB. NET ON SCALES	REV PER MIN.	LB. TANG PULL AT ONE FT. RAD.	REMARKS
1						1	10	100	337	525	
2						2		93	339	488	
3						3		92	338	483	
4	15	335	130	683		4	15	40	337	210	
4		344	115	604		5		45	344	237	
5	18	328	205	1075		6		28	345	147	
6		335	190	995		7					
7	20	314	224	1178		8					
8		312	220	1152		9	20	40	330	210	
9		311	219	1150		10					
10		330	210	1102		11					
11		334	195	1002		12	20	51	342	265	
12		334	200	1050		13		35	342	184	
13		335	193	1005	Smoke	14		57	342	298	
14		291	212	1110		15					
15		335	173	908		16					
16		290	205	1075		17					
17		280	230	1210		18					
18						19	28	100	339	525	
19						20	33	105	337	550	
20	48	271	269	1413	no slip						
21	48	255	280	1470							
22	55	287	287	1500							


1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
TANGENTIAL LOAD IN LB. AT ONE FOOT RADIUS
0
20
40
60
FORCES IN LB. AT END OF OPERATING LEVER.
no slip
16"
DISC FURNISHED BY
WILMINGTON FIBRE SPECIALTY Co.
WILMINGTON, DELAWARE.
CURVES
SHOW RELATION BETWEEN THE
LOAD, APPLIED AT THE CLUTCH
LEVER AND THE TANGENTIAL
LOAD
RED FOR LOAD TRANSMITTED.
BLACK " " PICKED UP.

DATA - 9

14" FIBRE DISC - WILMINGTON FIBRE SPECIALTY CO.

TRANSMIT						PICK UP					
Nº	LB AT END OF LEVER	REV PER MIN	LB NET ON SCALES	LB. TANG PULL AT ONE FT. RAD.	REMARKS	Nº	LB. AT END OF LEVER	REV PER MIN	LB. NET ON SCALES	LB. TANG PULL AT ONE FT. RAD	REMARKS
1	8	333	70	365							
2	9	334	55	289							
3	10	335	51	265							
4	10	333	73	383							
5		334	101	530							
6		334	104	535							
7		334	105	550							
8	12	388	61	320							
9		334	35	184							
10		334	30	157							
11		334	38	197							
12		332	55	284							
13		334	45	237							
14	22	334	97	509							
15		334	99	520							
16	24	334	100	525							
17		334	92	482							
18	25	333	75	383							
19		338	79	415							
20		338	78	409							
21	28	336	102	535							
22		335	78	409							
23		336	78	409							
24	38	170	305	1650							
25		180	295	1550							
26	50	328	98	515							
27		327	97	509							
28	53	327	106	556							
29		314	117	615							
30		312	140	735							
31	60	304	142	745							


TANGENTIAL LOAD IN LB AT ONE FOOT RADIUS
800
700
600
500
400
300
200
100
0
0
20
40
60
FORCES IN LB. AT END OF OPERATING LEVER.
14"
DISC FURNISHED BY
WILMINGTON FIBRE SPECIALTY CO.
WILMINGTON, DELAWARE
CURVE
SHOWS RELATION BETWEEN THE
FORCE APPLIED AT THE CLUTCH
LEVER AND THE TANGENTIAL
LOAD PICKED UP.

DATA-10

12" FIBRE DISC - WILMINGTON FIBRE SPECIALTY Co.

TRANSMIT						PICK UP					
No	LB. AT END OF LEVER	REV. PER MIN	LB NET ON SCALES	LB. TANG PULL AT ONE FT. RAD.	REMARKS	No	LB AT END OF LEVER	REV. PER MIN.	LB. NET ON SCALES	LB. TANG PULL AT ONE FT. RAD.	REMARKS
1	12	322	230	1208		1	12	334	30	157	
2		330	188	986		2		336	15	73	
3		324	231	1212		3		334	27	142	
4	15	336	205	1076		4	15	334	35	184	
5		316	230	1208		5		338	20	105	
6		332	195	1012		6		336	25	131	
7		316	235	1232		7		334	35	184	
8		322	245	1286		8					
9		320	245	1286		9		336	39	205	
10	20	330	200	1050		10	20	340	28.	137	
11		328	198	1038		11		336	40	210	
12		332	190	997		12		336	32	168	
13		328	188	976		13		336	29	152	
14	37	300	245	1286		14					
15		328	245	1286		15	37	336	37	252	
16		334	155	815		16		340	38	197	
17	55	180	345	no slipping.							
18	97	190	315	"	"						
19		195	323	"	"						

DATA-11(a)

18" FIBRE DISCS - CONTINENTAL FIBRE CO.

TRANSMIT						PICK UP					
No	LB. AT END OF LEVER	REV. PER MIN	LB NET ON SCALES	LB. TANG PULL AT ONE FT. RAD.	REMARKS	No	LB AT END OF LEVER	REV. PER MIN	LB. NET ON SCALES	LB. TANG PULL AT ONE FT. RAD.	REMARKS
1	7	342	175	915		1	7	348	15	78	
2		342	150	785		2		347	13	68	
3		338	184	965		3		347	13	68	
4		334	215	1230		4		348	14	73	
5		340	165	865		5		348	20	105	
6		338	190	996		6		347	20	105	
7		334	230	1209		7		346	20	105	
8		338	213	1114		8		347	20	105	
9		334	245	1283		9		346	24	126	
10	8	342	155	815		10	8	348	13	68	
11	10	336	215	1230		11	10	346	30	157	
12						12	9	344	45	237	
13						13		344	70	367	
14						14	8	344	55	289	
15						15	10	344	40	210	
16						16		344	60	315	
17						17		344	70	367	
18						18		344	72	378	
19	11	342	151	793		19	11	348	15	78	
20	12	306	255	1340		20	12	350	35	184	
21		348	140	735		21		352	25	131	
22	13	350	115	610		22	13	354	25	131	
23		336	240	1260		23		346	15	78	
24		332	255	1340		24		346	19	100	
25		336	187	980		25		347			
26	15	348	115	610		26		350	30	157	
27		346	120	630		27		348	22	115	
28		346	120	630		28		352	25	131	
29		348	130	683		29		353	25	131	
30		334	295	1550		30		346	81	425	
31						31	16	343	55	289	
32	16	342	185	965		32		350	30	157	
33						33	17	343	45	237	
34						34		344	42	220	
35						35		342	37	194	
36	18	350	165	865		36	18	354	25	131	
37		336	195	1030		37		346	37	194	
38		346	170	893		38		352	30	157	
39	20	348	140	735		39	20	354	25	131	
40		350	155	815		40		356	30	157	
41	21	342	158	830		41		348	52	273	
42	22	344	202	1050		42	22	343	52	273	
43		306	250	1310		43		346	34	179	
44	23	338	215	1230		44	23	350	30	157	
45		336	205	1070		45		348	30	157	
46	24	328	157	825		46		346	36	189	
47	25	305	255	1340		47		346	75	394	
48		304	255	1340		48		350	105	550	

DATA 11(b)

18" FIBRE DISCS - CONTIEENTAL FIBRE CO.

TRANSMIT						PICK UP					
No	LB. AT END OF LEVER	REV. PER MIN	LB. NET ON SCALES	LB. TANG PULL AT ONE FT. RADIUS	REMARKS	No	LB. AT END OF LEVER	REV. PER MIN	LB. NET ON SCALES	LB. TANG PULL AT ONE FT. RADIUS	REMARKS
49	27	280	275	1442		49	27	346	36	189	
50						50		344	67	352	
51						51		344	62	326	
52						52		344	61	320	
53						53		345	63	332	
54						54		344	69	362	
55						55	29	345	75	394	
56						56		345	73	383	Smoke-cooled.
57	34	340	205	1075		57	34	350	36	189	
58						58	35	341	140	738	
59						59	41	344	120	630	
60						60		341	145	760	
61						61	44	344	105	550	
62						62		346	90	472